Observation of Coherent Neutrino-Nucleus Scattering at a Nuclear Reactor

S. Sangiorgio, A. Bernstein, J. Coleman, M. Foxe, C. Hagmann, T. H. Joshi, I. Jovanovic, K. Kazkaz, K. Movrokoridis, S. Pereverzev.

Coherent scattering of neutrinos on nuclei is an undisputed prediction of the standard model [1] that has so far eluded experimental observation. The only detectable signature of such interaction – a low-energy (<~10keV) nuclear recoil – has been so far out of reach due to the technical difficulties in developing large-scale detectors capable of such low thresholds. In recent years, progress in dark matter searches using noble-liquids has provided a detector technology that brings CNNS within grasp [2]. Nuclear reactors are an attractive source of neutrinos for CNNS investigations. They provide a high flux of neutrinos ($\Phi > 10^{12}$ cm^{-2} s^{-1}) with energies up to about ~ 10 MeV.

Drawing from the experience of dark matter dual-phase detectors with noble liquids, we propose the realization of a 10-kg dual-phase argon detector to be deployed at a nuclear reactor site. Feasibility of CNNS in liquid argon depends on the ionization yield of sub-keV nuclear recoils in this medium. This quantity is currently unknown at these energies. Existing simulations (including our own), needs to be verified experimentally. LLNL has developed a prototype detector and a quasi-monochromatic low-energy neutron beam to perform these measurements [3]. Detector sensitivity to single ionization electrons produced in the liquid is needed. This was demonstrated in the LLNL prototype [4].

A preliminary design of the 10-kg detector has been performed, taking advantage of LLNL's expertise in fielding detectors at nuclear reactors. Backgrounds were also estimated [5]. The shallow-depth reactor location requires proper shielding. Once shielded, ^{39}Ar is expected to be the largest background component. Instrument-induced backgrounds, in particular single electrons, need to be carefully studied and controlled.

Assuming perfect efficiency in detecting single primary electrons, ~170 events/day are expected in the 10-kg detector. If the neutrino signal follows reactor outages, we would have the first observation ever of coherent neutrino scattering.

The results and detector capabilities required for CNNS detection in liquid argon will contribute to dark matter searches for light-mass WIMPs and to axion searches via the axio-electric effect.

Aside from validating core elements of the Standard Model or provide indications of physics beyond it, the detection of CNNS has other interesting applications. The interaction is in fact flavor-blind thus allowing to monitor the total neutrino flux in neutrino oscillation experiments and nearby supernova explosions [6]. CNNS has also been considered for probing sterile neutrinos [7], measuring nuclear form factors [8], as well as in nuclear reactor monitoring and safeguard [5].

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